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EP 0841574 A2	EP 0364151 A2	EP 0330347 A1
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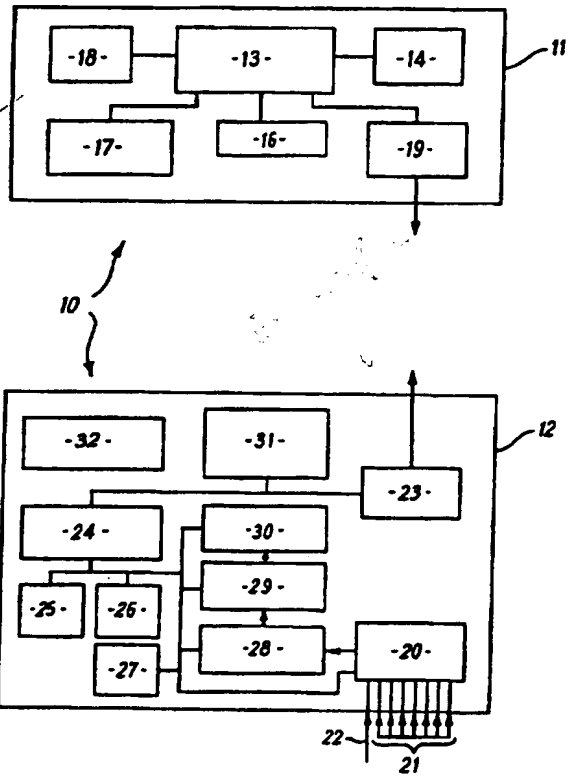
(54) Abstract Title
Monitoring condition of a machine

(57) A system 10 for monitoring the condition or state of a machine, has a controller 11 coupled by an infra-red, radio or hard-wire link to an interface device 12 located on the machine to be monitored. One or more ports 21 receive signals from machine transducers. The signals are processed 28,29,30,31 and may be stored in memories 25,26,27. The processed signals are sent from an interface port 23 to a controller port 19. The controller has a display 18 and a microprocessor 13, and supplies instruction signals via the ports 19,23 to control the manner of operation of the interface device.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date but within the period prescribed by Rule 25(1) of the Patents Rules 1995.

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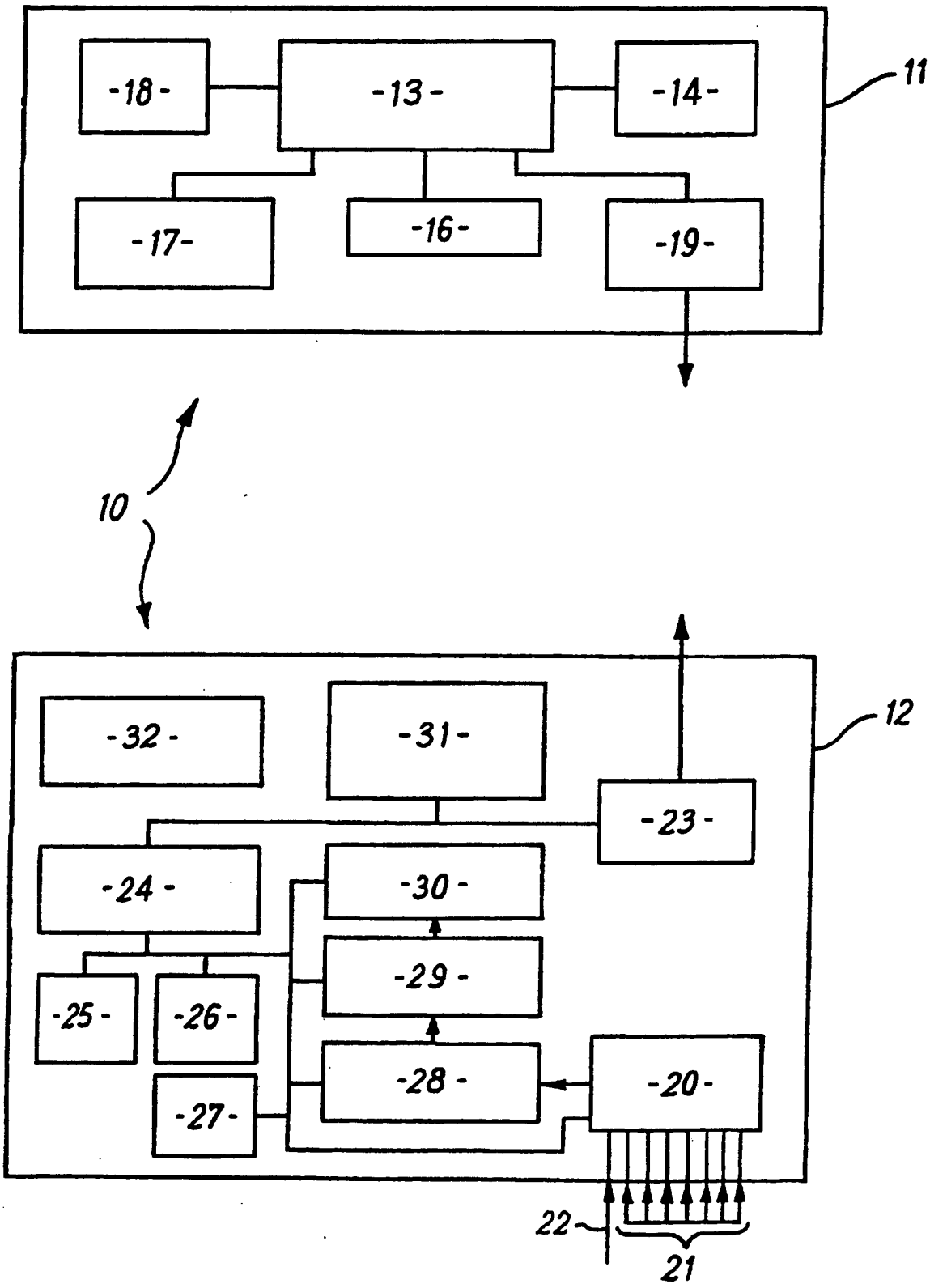
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MACHINE CONDITION MONITORING APPARATUS AND METHOD

The invention relates to machine condition monitoring apparatus such as is conventionally used to determine a running condition and maintenance state of machinery such as, for example, conveyor systems and vehicle or marine engines.

Monitoring of machines is important to ensure that timely routine maintenance or necessary adjustment can be carried out to prevent long term damage to the machine. Monitoring is also useful in obtaining information which can assist in predicting whether machine failure is likely to occur. For example, information can be obtained which indicates when wear, malfunction or degradation in performance of the machine has occurred which can be indicative of the onset of failure. A monitoring regime can allow identification of potential problems and can allow the machine to be stopped, or repaired, before machine failure which could lead to destruction of the machine and may present safety risks to personnel and/or other machinery in the vicinity of the failed machine.

Monitoring of machine condition is usually carried out using one or more of a number of conventional techniques for example visual inspection, audible inspection, temperature monitoring, oil analysis (tribology), hydraulic or other pressure monitoring, fuel or energy consumption monitoring, vibration monitoring, machine load and output monitoring. Some of these techniques are suitable for automation whilst others require manual

implementation. Temperature, pressure, vibration energy consumption and machine load and output are all examples of parameters that can be measured using available electronic sensors. These are suitable for measurement using automated equipment.

Conventional apparatus for monitoring machine condition is generally categorised as either on-line or off-line apparatus.

On-line condition monitoring apparatus is permanently connected to the machine whose condition is being monitored and will continuously monitor various selected parameters indicative of machine condition and may cause an alarm signal to be generated if predetermined safe values for those parameters are exceeded.

Off-line apparatus has to be connected to a machine by a human operator. Once readings have been taken the apparatus is disconnected from the machine.

On-line apparatus is generally expensive, is complex to install and requires routine inspection by an engineer to ensure correct operation. Also, a respective on-line apparatus has to be provided for each machine to be monitored. Off-line apparatus is relatively inexpensive but has increased running costs due to the need for a human operator, particularly where frequent monitoring is required. However, a single off-line apparatus can be used to monitor more than one machine at any one time by simple connection and disconnection to the selected machine.

Conventional off-line machine condition monitoring apparatus comprise small bespoke portable devices operated by an onboard power supply, e.g. battery. Connectors are provided to allow connection to one or more transducers provided on a machine to be monitored. Values measured by the transducer are read by the apparatus and stored in a memory and/or displayed on a suitable built-in display in a very rudimentary form.

Usually, with this type of off-line apparatus the stored values are input into a suitably programmed computer for appropriate processing into a form suitable for more user friendly display. This means that, usually, an instantaneous decision on the condition of a machine cannot be made from these measured values until they have been processed by a computer.

The present invention relates to a machine condition monitoring apparatus of both the off-line and on-line types.

It is an object of the present invention to provide machine condition monitoring apparatus which overcomes or at least minimises the problems associated with conventional such apparatus.

It is another object of the present invention to provide an off-line machine condition monitoring apparatus that delivers at least the same functionality as existing meters, but which is easier and more economic to produce.

It is a still further preferred object of the invention to provide

improved on-line condition monitoring apparatus with the support of a further supervising computer.

According to an aspect of the present invention there is provided machine condition monitoring apparatus comprising an interface device providing at least one input channel adapted to receive a signal from a transducer monitoring a parameter of a machine to process said signal and transmit the processed signal to a control device wherein said interface device is also adapted to receive an instruction signal transmitted by the control device and wherein the manner of operation of the interface device is dependent upon the signal received.

For the purposes of receiving a signal from a transducer the interface device preferably includes an input. The input is preferably internally configurable. The input may provide a plurality, e.g. up to eight, channels by way of a multiplexer. The input preferably enables the device to be connected to standard voltage sources, standard 4-20mA transducers and standard a.c. accelerometers.

The interface device preferably has one of the input channels arranged to act as a trigger for synchronous monitoring. This channel is preferably thresholded.

To enable suitable processing of a signal received from a transducer the interface device preferably also includes a microprocessor. Support circuitry may also be provided, for example an electronic memory and

control device. Preferably both Random Access Memory (RAM) and Read-Only Memory (ROM) are provided.

The interface device preferably also includes transducer interface circuitry for the input, pulse shaping and triggering circuitry for the trigger channel, an analogue to digital converter (ADC) and a digital filter. Each of these components are preferably programmable or configurable under control of the microprocessor.

To enable the interface device to communicate with a control device it preferably includes a standard serial interface, for example an RS232, RS485 and/or IRDA interface. The interface unit may communicate with a control device by wire, infra-red, radio or any other suitable technique.

The interface device is preferably disposed in a housing. The housing is preferably sized so that it may be comfortably held in one hand. The interface unit preferably has a mass less than 100g.

It is preferable that the interface device has an onboard power supply. This is preferably a rechargeable battery. Additionally, provision for connection of an external power supply could be made which could be used to recharge the battery.

Some or all of the above elements may be combined as part of a single integrated silicon device or unit.

The control device preferably includes a means for communicating with an interface device, to transmit instructions thereto and to receive

processed signals therefrom, a processor and an electronic memory.

The apparatus may be used for either on or off-line machine condition monitoring. When used as off-line apparatus the control device preferably also includes a user operable control and a display.

The control device is preferably programmable. The user operable control and display may be combined, for example as a touch sensitive screen.

For off-line use the control device may be arranged to guide a user, to instruct an interface device to take measurements, to receive and process those measurements and present them in a user-friendly manner. In this case the control device preferably comprises a personal computer (PC), more preferably it comprises a hand held personal computer, for example a so-called palm top PC. Such equipment is, of course, readily available. The control device preferably includes means to record speech to allow recording of observations during monitoring of a machine.

For off-line use the control device is preferably arranged so that it may be programmed with a list of predetermined monitoring "jobs" and to prompt a user to monitor a particular component either by connecting the interface unit to the required transducer to allow readings to be taken or simply to make observations and enter these into the control device. Preferably, it is possible to schedule each job to repeat on a routine basis, to ensure that the user does not forget to do jobs and to ensure that

scheduled jobs are carried out with the proper frequency. Job types may include audible and visual inspection checks, manual parameter readings of any type (temperature, pressure, overall vibration level, etc.), automatic parameter readings, for example using a standard transducer or vibration interfaces, including spectra and time value readings.

The control device is preferably arranged to display a visual representation of the equipment or site to be monitored. Particularly, it may display a plant map view and a tree view.

The plant map view may comprise a series of images which show the layout of the site containing the monitored machines at increasing levels of details. This hierarchical display will allow the operator to begin the routine monitoring process at the highest level and then "zoom in" through each picture to access each of the machines and their configured monitoring jobs in detail.

The tree view may show the underlying hierarchy of configuration without plant map images, as an alternative and possible operator preferential means of running through schedule activities.

Where monitoring jobs are automatic, the control device may instruct the user on what connections are required to be made to form the interface unit and transducers and will then record the relevant parameters. Where monitoring jobs are manual, the control device may prompt the operator to take a manual reading using some external device or meter, and to then

enter the results into the device.

The control device may also provide review facilities including a trend display to show the long term variance of measured parameters, a spectra display to show phase and amplitude spectra obtained through vibration monitoring and a time value display to show the "sampled" readings taken as part of the vibration monitoring process.

The device may also provide a facility to review alarms generated by the meter in response to parameter readings that are outside configured acceptable limits.

The device may also provide communication facilities to upload information to other analysis packages, to download information to configuration packages and, as an option, to utilise a built-in modem on the control device to send this information over long distances.

When used for on-line monitoring of machine condition, the input channels of the interface device would be permanently connected to one or more transducers. The interface device would also be in permanent communication with the control device, for example via a direct cable or network cable connection, allowing the interface device to be installed in a remote location.

In particular, for on-line monitoring, it is preferred that a single control device is connected to a plurality of interface devices. The control unit may then be used to schedule monitoring jobs. For on-line monitoring it is

preferable that the control device also includes a modem, or other suitable transmission means, to enable data collected to be transmitted to a remote control centre for analysis.

A modem may also be included in control units used for off-line analysis, again to enable collected data to be transmitted to a remote control centre.

According to a further aspect of the present invention there is provided a method of monitoring the condition of a machine comprising the steps of:

connecting an interface device to a transducer mounted on the machine arranged to take and process a reading on instructions and to transmit the processed reading to a control device;

transmitting instructions to the interface unit to take a reading using a control device;

receiving a signal from the interface device with the control device, the control device being arranged to process the received signal to determine and display or store the reading.

The instruction signal may include any or all of the following information:-

- Reading type - for example continuous data sample, external trigger
- Signal condition

- Sample frequency
- Number of samples

In one embodiment the instructions received by the interface unit cause it to perform the following steps:-

i) Configure an ADC on the interface device for either a single or multiple reading

ii) Configure a digital filter on the interface device to remove appropriate unwanted frequency elements from the signal. Slow moving readings such as temperature, pressure and other readings are typically screened to remove known sources of "noise" such as 50Hz mains pickup or motor running frequencies. The digital filter may be configured to "notch" out such unwanted values to improve reading accuracy. Vibration readings require lots of frequency information to be present in the readings taken, but still require that the frequencies being measured are limited. Again the digital filter may be configured to remove the appropriate unwanted frequencies.

iii) Configure transducer interface circuitry on the interface device. The interface device input may be able to connect to a variety of signal sources, for example standard voltages up to +/- 5V DC, 4-20mA standard loop, standard AC accelerometers. Each type of input will require separate interface circuitry to be switched "in-line" to protect the interface device and to obtain suitable voltages for the

filter and ADC stages.

iv) Configure trigger circuitry on the interface device. In the case of time synchronised vibration monitoring, the trigger circuit will need to be configured and set up to trigger the ADC into commencing a sample.

v) Wait for or commence a reading cycle using the configured elements.

vi) Post process the information returned from the elements to make it suitable for transmission digitally to the control device in digital form.

The interface device will then notify the control device that the requested reading is available. The control device will request the reading information in digital format which will be transmitted via a RS232, IRDA or radio data link or the like.

The control device will then store, manipulate and further process the received information as required to make it suitable for display to the operator. Alternatively and/or additionally the control device may transmit processed or unprocessed information to a remote control centre, for example by use of a modem.

The interface device may perform auto-ranging functions whilst taking readings to ensure that the maximum dynamic range of the ADC is used.

One control device may be used to control one or more interface

devices, which are all preferably configured with a unique address code.

The invention provides a convenient to use and economic means for monitoring machine condition principally through transducers, but may also aid manual monitoring.

When a wireless link is provided between interface and control devices this enables the user to retire to a safe distance from the interface unit to take readings while a machine operates. This may be desirable when the apparatus is used for off-line monitoring.

When the control device is used to guide the user when used for off-line monitoring, a typical usage pattern may comprise:-

- Activating the device and using map view to determine which areas of plant require attention.
- Zooming down the map view levels to section and ultimately area view, determine which means and which monitoring jobs are due.
- By selecting each monitoring job, review the actions required; manual or automatic.
- In the case of manual actions, perform those actions and enter the results.
- In the case of automatic actions, connect the interface unit to the correct transducer and take an automatic reading.
- On completion of the reading (manual or automatic), perform a brief review against previous readings to check for wildly abnormal readings.
- Continue on the monitoring cycle until all monitoring jobs for the day have

been completed.

A typical readings review session may be:-

- Using the map view, determine which areas of the plant are "in alarm" - indicating that readings taken indicate an abnormal condition.
- Review the magnitudes of readings and their nature to determine the seriousness and possible nature of the fault. This action may require comparison with previous readings.
- Plan remedial action and, if necessary, schedule extra monitoring readings to check a "return to normal" condition has been achieved.

Alternatively, this process may be performed at a data analysis centre once information has been collected, for example when the apparatus is used for on-line monitoring.

In order that the invention may be more clearly understood an embodiment thereof will now be described by way of example with reference to the single figure of the accompanying drawings which show:-

a block circuit diagram of a control device and

interface device according to the invention.

Referring now to the drawings, there is shown machine condition monitoring apparatus 10 according to the invention which comprises a control device 11 arranged to communicate with one or more interface devices 12 adapted for connection to one or more transducers monitoring selected parameters of a machine.

The control device 11 comprises a programmed microprocessor 13 connected respectively to a suitable power supply 14, a user operable control 16, a suitable memory 17, a display 18 and a communication device 19 which enables the control device to communicate with the interface device 12. The display 18 comprises a liquid crystal (LCD) or light-emitting diode (LED) colour display of conventional form and is used to display instructions or selected options to a user and data obtained from readings.

The memory comprises conventional Random Access Memory (RAM) or Read-Only Memory (ROM).

The user operable control 16 may comprise a keyboard, mouse or other arrangement and may be formed integrally with or connected to the control device 11. Alternatively, the display 18 and user operable control 16 can be combined whereby the display is of a touch sensitive kind.

The illustrated control device 11 is particularly, but not exclusively, intended for off-line use and is preferably effected by a hand held or palm top PC. Where the control device is intended for on-line use then it may be implemented by a fixed embedded PC and the on-board power supply 14, user-operable control 16 and display 18 may be deleted. In which case it is desirable that an additional communication means, for example a modem, is provided to enable the control device to communicate with a control centre.

The communication device 19 comprises a standard communication

serial port of a type commonly referred to by the reference RS232 and RS485. The communications port may be configured so as to allow communication with the interface device 12 by way of infra-red radiation, radio waves or direct wire connection.

The interface device 12 comprises an input port having eight input channels. Seven of these provide an input channel 21 adapted for connection to a transducer monitoring a parameter of a machine. The remaining channel 22 is a trigger input 22 for time synchronisation. The interface device 12 also includes a communication port 23 of a similar type to that provided in the control device 11. The input channels 21, 22 are connected to a multiplexer 20 which connects the inputs in sequence to the main circuit.

The interface device 12 further comprises a main microprocessor 24 which is connected to memory devices which are respectively a Random Access Memory 25 (RAM) Read-Only Memory 26 (ROM) and flash RAM 27 type. The main microprocessor 24 is also connected to the communication device 23 and via signal processing circuitry, to the primary input ports 21 and the trigger port 22. The signal processing circuitry comprises a programmable signal conditioning device 28 linked to a programmable digital filter which is in turn linked to an analogue to digital converter 30. The digital filter 29 and signal conditioning device 28 operate in accordance with instructions given by the main microprocessor 24 in a manner to be

described hereinafter.

The interface device also comprises a secondary microprocessor 31 which is adapted to interact with the main microprocessor and cause modification or reprogramming of the main microprocessor 24.

The interface device also comprises a power supply 32 which may also include circuitry to control the power supplied to the device.

In use the interface device 12 is connected to the transducer or transducers whose readings it is desired to take via the primary input port 21 of the interface device 12. The trigger input 22 is also connected, where appropriate.

This received signal is then processed by the signal processing circuitry. As mentioned previously, the signal conditioning means 28 and digital filter means 29 are programmable and are under the control of the main microprocessor 24, which controls their operation to ensure that they process the signal received from the transducer in a manner which is appropriate for that particular signal received. Thus, for example, depending of the type of transducer to which the primary input 21 is connected, it may be appropriate to take only a single sample of a signal in order to provide an accurate reading. Alternatively, it may be necessary to take several sample readings. Therefore, the main microprocessor is programmed appropriately for the type of transducer to which the input 21 is connected and appropriately configures the digital filter 29 and signal 28

conditioning device to filter out unwanted signals and condition the signal produced into a form suitable for taking a reading.

The main processor software is responsible for listening for commands from the interface unit, decoding and responding to them. On receipt of a command it will:

Verify the command format

Acknowledge receipt

Select an appropriate signal conditioning mode

Select an appropriate filter configuration and program the digital filter

Select an appropriate ADC configuration and program the ADC

Select an appropriate triggering mode: internal or external

Inform the control device of readiness to commence

On receipt of start command, enable recording

Monitor the recording process

On completion, indicate status to control device

Process commands to upload recorded signal information to control device

Other ancillary functions may include:-

Self testing internal circuitry at power up

Monitoring internal voltage levels to indicate when the battery needs to be recharged.

This processed signal is then communicated to the control device 11

via the communication device 23. Once received by the control device 11, the signal may be further processed in the microprocessor into a form suitable for display on the display and/or storage in the memory or, in the case of on-line operation for subsequent uploading to a control centre.

The control device could also be used to prompt a user.

It is of course to be understood that the invention is not intended to be restricted to the details of the above embodiments which are described by way of example only.

CLAIMS

1. Machine condition monitoring apparatus comprising an interface device providing at least one input channel adapted to receive a signal from a transducer monitoring a parameter of a machine, the interface device being adapted to process said signal and transmit the processed signal to a control device wherein the interface device is also adapted to receive an instruction signal transmitted by the control device and wherein the manner of operation of the interface device is dependent upon the signal received.

2. Apparatus as claimed in claim 1, wherein the interface device comprises a plurality of input channels.

3. Apparatus as claimed in claim 2, wherein one of the input channels is arranged to act as a trigger for synchronous monitoring.

4. Apparatus as claimed in any preceding claim, wherein the interface device includes a microprocessor and an electronic memory.

5. Apparatus as claimed in claim 4, wherein the interface device also includes transducer interface circuitry for the input, pulse shaping and triggering circuitry for any trigger channel, an analogue to digital converter (ADC) and a digital filter.

6. Apparatus as claimed in any preceding claim comprising a control device, the control device including a means for communicating with the interface device, to transmit instructions thereto and to receive

signals therefrom, a processor and an electronic memory.

7. Apparatus as claimed in claim 6, wherein the control device is programmable and includes a user operable control and a display.

8. Apparatus as claimed in claim 7, wherein the control device is arranged to guide a user, to instruct an interface device to take measurements, to receive and process those measurements and present them in a user-friendly manner.

9. Apparatus as claimed in claim 8, wherein the control device is arranged so that it may be programmed with a list of predetermined monitoring "jobs" and to prompt a user to monitor a particular component or a machine either by connecting the interface unit to the required transducer to allow readings to be taken or to make observations and enter these into the control device.

10. Apparatus as claimed in any of claims 7 to 9, wherein the control device is arranged to display a visual representation of the equipment or site to be monitored.

11. Apparatus as claimed in claim 6, wherein the input channel or channels of the interface device are permanently connected to one or more transducers and to the control device.

12. Apparatus as claimed in claim 12 comprising a plurality of interface devices connected to a single control device.

13. Apparatus as claimed in any of claims 6 to 12, wherein the control

device includes a modem.

14. A method of monitoring the condition of a machine comprising the steps of:

connecting an interface device to a transducer mounted on the machine, the interface device being arranged to take and process a reading on instructions and to transmit the processed reading to a control device;

transmitting instructions to the interface device to take a reading using a control device;

receiving a signal from the interface device with the control device, the control device being arranged to process the received signal to determine and display or store the reading.

15. A method as claimed in claim 14, wherein the instructions transmitted to the interface device include any or all of the following information: reading type, signal condition, sample frequency and number of samples.

16. A method as claimed in either claim 14 or 15, wherein the signal received by the interface unit causes it to perform the following steps:

i) configure an ADC on the interface device for either a single or multiple reading;

ii) configure a digital filter on the interface device to remove appropriate unwanted frequency, elements from the signal;

iii) configure transducer interface circuitry on the interface device;

iv) wait for or commence a reading cycle using the configured elements; and

vi) post process the information returned from the elements to make it suitable for transmission digitally to the control device in digital form.

17. A method as claimed in claim 16, wherein the interface device subsequently notifies the control device that the requested reading is available and the control device then requests the reading information.

18. Machine conditioning and monitoring apparatus substantially as herein described with reference to the accompanying drawings.

Application No: GB 9908737.1 23 **Examiner:** David Brunt
Claims searched: 1-18 **Date of search:** 7 August 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H2K (KJBC, KSD1X, KSD9)

Int Cl (Ed.7): G01R (31/34), G07C (3/00)

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,E	GB 2343253 A	(CSI) see Fig.3	1 and 14 at least
X,E	GB 2339284 A	(CSI) see Fig.2 & page 13 line 2-p.14 line 5	1 and 14 at least
X,E	GB 2338848 A	(CSI) see Fig.5 & page 18 lines 4-11	1 and 14 at least
X	EP 0841574 A2	(RELIANCE) see Figs.2 & 3	1 and 14 at least
X	EP 0364151 A2	(TEXAS) see Fig.1	1 and 14 at least
X	EP 0330347 A1	(DICKEY-JOHN) see page 5 lines 13-19	1 and 14 at least
X	WO 98/45779 A1	(CSI) see whole document	1 and 14 at least
X	WO 98/08292 A1	(CSI) see Fig.5 & page 13 lines 8-15	1 and 14 at least
X	US 4559828	(LISZKA) see whole document	1 and 14 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.